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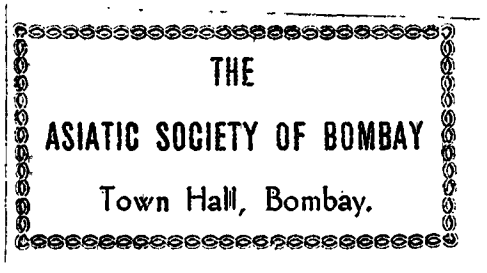

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J. Donaldson del. *J. Basire Sc.*

A CONCISE

ESSAY ON MAGNETISM;

WITH

AN ACCOUNT OF THE DECLINATION AND INCLINATION

OF THE

MAGNETIC NEEDLE;

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a c

AND

AN ATTEMPT TO ASCERTAIN THE CAUSE OF THE VARIATION THEREOF.

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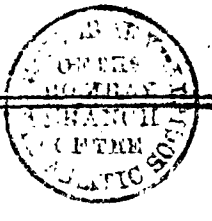
BY

JOHN LORIMER, M. D.

AND FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS OF EDINBURGH.

Veniet tempus quo ista quæ nunc latent, in lucem dies extrahet, et longioris ævi diligentia.—Tempus veniet quo posteri nostri tam aperta nos nescisse mirentur.—SENECA NAT. QUEST. L. VII. c. 25.



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TO

HIS ROYAL HIGHNESS

THE DUKE OF CLARENCE,

THIS ESSAY ON MAGNETISM

IS,

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BY

HIS ROYAL HIGHNESS's

MOST OBEDIENT AND

MOST HUMBLE SERVANT,

J. LORIMER.

A

SHORT HISTORICAL ACCOUNT

OF THE

DISCOVERY OF MAGNETISM,

AND OF THE

MAGNETIC NEEDLE.

Origin of the name.

1. IT would be to little purpoſe at this time to inquire particularly whether the Magnet had its name from the ſhepherd Magnus, who, as Nicander and Pliny affirm, diſcovered it upon Mount Ida by the iron of his crook, and the nails in his ſhoes; or whether it was ſo titled from Magneſia, that part of Lydia, where, according to Lucretius, it was firſt found. The Grecians, indeed, who were acquainted with the various names it then went by, and likewiſe with its attractive property, have ſometimes called it Siderites, from σιδηρος, iron; but more frequently the Heraclean ſtone, from the city Heraclea in Magneſia; and Snellius may be right in ſaying, that Euripides was the firſt who gave it the name of Magnes, though Sophocles called it *Lapis Lydius*.

2. With

Attractive property.

2. With reſpect to the properties of the magnet, father Kircher endeavours to prove, that its attraction was known to the Hebrews; and from Plutarch it ſeems to appear, that the Egyptians were not ignorant of it. Pythagoras, Ptolemy, Hippocrates, Empedocles, Democritus, Leucippus, Epicurus, and many more of the ancients, knew and admired this wonderful property of the magnet. It was on account of this quality that Thales and Anaxagoras gave it a ſoul; and Plato, who called it the ſtone of Hercules, ſaid, that the cauſe of its attraction was divine. Alſo Ariſtotle, Theophraſtus, Dioſcorides, Galen, and others amongſt the ancients, have made particular mention of it.

Invention of the mariner's compaſs.

3. The diſcovery of the verticity or directive property of the magnet or loadſtone, and the communication of that verticity to iron, or, in other words, the invention of the mariner's compaſs, though only a conſequence of the former property, appears to be but of a modern date. It is indeed pretended, that the eaſtern nations were well acquainted with this property of the magnet, long before the Europeans had learned any thing about it. Some ſay that Solomon knew the uſe of the compaſs, and that thereby he was enabled to ſend his mariners to Peru, which was then called Parvaim

vaim and Ophir *. Other authors affirm, that the Chineſe about that time, or even earlier than the days of Solomon, were acquainted with this moſt uſeful quality of the magnet. This, however, has been much doubted †.

Flavius Blond affirms, that in or about the year 1302, one John Goia, a noble citizen of Amalphi, a town of Principato, in the kingdom of Naples, firſt diſcovered the mariner's compaſs; and for this he quotes the following verſe from Antony of Palermo, recorded by the Neapolitan hiſtorians; viz.

Primo dedit nautis uſum magnetis Amalphi.

The arms of the territory of Principato has, it ſeems, ever ſince been a mariner's compaſs. It has alſo with equal confidence been aſſerted, that Marco Paulo, the Venetian, learned the uſe of the mariner's compaſs from the Chineſe; and that he firſt made it known in Italy about the year 1260. But this cannot be true; for M. Paulo did not ſet out on his journey to China before the year 1269, nor did he return before the year 1295 ‡. It ſeems however from the documents, which will be ad-

* See Pineda de rebus Solomonis. L. iv. c. 15.

† See Du Hald's Hiſtory of China, and the learned Renaudot's Diſſertation on the Chineſe Sciences, &c.

‡ See Purchaſe's Pilgrim, vol. III.

duced

duced in the ſequel, that the directive property of the magnet, and the communication of that property to iron, was known in Europe before this time; though to all probability it was not uſed in navigation till ſome time after; which may very reaſonably be attributed to the clumſy way of ſuſpending the magnetic needle, which was at firſt uſed *.

In the works of Claude Fauchet, entitled, *Recueil de l'origine de la Langue et Poeſie François*, fol. 555, there is a quotation from an old French poem, called *la Bible Guiot*, in which the mariner's compaſs is evidently mentioned. This ſame paſſage is likewiſe quoted by Muſchenbrock, in his *Diſſertatio de Magnete*. The ſingularity of this paſſage having excited my curioſity, I made ſome enquiry after the above-mentioned old poem, in conſequence of which, I found that there was a curious and intereſting quarto manuſcript of the 13th century, on vellum, in what was then juſtly called the Royal Library at Paris. The firſt article in this manuſcript book, which was never publiſhed, is *la Bible Guiot*;

* The aſſertion of Dr. Wallis ſeems to be well founded; viz. that the magnetic needle, or compaſs, was brought to perfection by gradual ſteps and partial improvements, and that of theſe the Engliſh may claim conſiderable ſhare.

the author of which, viz. *Guiot de Provins*, as mentioned in the poem itſelf, was at the court of the Emperor Frederic Barbaroſſa, held at Mentz in the year 1181, when the emperor's two ſons were knighted *.

Here follows this remarkable paſſage, extracted from *la Bible Guiot*, in its original antiquated language, which has perhaps ſuffered much from the careleſſneſs of tranſcribers, as may appear from the ſubjoined notes. The tranſlation, which follows this paſſage, was made by a native of Provence, and as literal as poſſible.

* See Chron. Abbot. Urſperg. p. 311.

EXTRACT FROM LA BIBLE GUIOT.

Icelle eſtoile ne ſe muet,
Une arts ſont qui mentir ne puet,
Par la virtu de la manete*
Une piere laide et brunete,
Ou il fers volenters ſe joint.
Ont regardent lor † droit point
Puez c' une aguile lont touchie,
Et en un feſtu lont fiſhie
En longue ‡ la mette ſens plus,
Et il feſtui la tient deſus;
Puis ſe torne la point toute
Contre leſtoile ſans doute,
Quant il nuis eſt tenebre et brune
Con ne voit eſtoile ne lune,
Lor † font a laguille alumer;
Puiz ne puent ils aſſorer,
Contre leſtoile vers la pointe;
Par ce ſont § il mariner cointe,
De la droite voie tenir;
C'eſt uns ars qui ne puet mentir.

* Manete, magnete, magnes, the loadſtone. This word is improperly written in different manuſcripts; as marinette, mariniere, marniere, &c. In the next line alſo, M. Fauchet has *noirette*, where it is *brunete* in my correſpondent's manuſcript.

† Lor, alors.

‡ An ingenious friend of mine obſerves, that *longue*, or *langue*, as ſome copies have it, may perhaps mean *l'eau*; and in the ſame line *mette*, may have been *mettent*.

§ Ce ſont, ſe ſont.

LITERAL TRANSLATION OF THE PRECEDING.

This ſame (the pole) ſtar does not move, (and)
They (the mariners) have an art which cannot deceive,
By the virtue of the magnet,
An ugly browniſh ſtone
To which iron adheres of its own accord.
Then they look for the right point,
And when they have touched a needle (on it)
And fixed it on a bit of ſtraw
Lengthwiſe in the middle, without more,
And the ſtraw keeps it above;
Then the point turns juſt
Againſt the ſtar undoubtedly,
When the night is dark and gloomy,
That you can ſee neither ſtar nor moon,
Then they bring a light to the needle;
Can they not then aſſure themſelves
Of the ſituation of the ſtar towards the point (of the needle?)
By this the mariner is enabled
To keep the proper courſe;
This an art which cannot deceive *.

* The expletive words, included in parentheſis in this tranſlation, were thought neceſſary to make it the more intelligible, though they are not in the original; only in my correſpondent's copy the ſecond line runs thus:

Une arts ſont (les Marins) qui mentir ne puet.

Gaſſendus adduces, as an argument of the French having been the inventors of the compaſs, that the north point thereof is always marked with a Flower de Luce*. As for Goropius's pretence, that the compaſs muſt be the invention of the Danes, Dutch, or Germans, becauſe the thirty-two points on it, are written, and pronounced in the Dutch or Teutonic language, has no better grounds than the Engliſh claim from the words Compaſs and Box †. Vincentius Belluacenſis, and Albertus Magnus, who lived about the year 1245, as well as Levinus Lemnius, make mention of the direction of the poles of the magnet, as from a tract *de lapidibus*, which had been attributed to Ariſtotle, but is ſuppoſed to have been the work of ſome Arabian author, a little before, or about, their own time, which tract has been ſince loſt.

Plautus in Mercatore, Act V. Scene II. has the following remarkable paſſage, viz. *Huc ſecundus ventus nunc eſt, cape modo vorſoriam.* Now ſome authors will have it, that by the word *vorſoriam* or *verſoriam*, is meant the mariners compaſs; ſome learned critics, however,

* Lib. x. Diog. Laert. T. i. p. 139.

† It appears, however, that thoſe nations were early acquainted with the uſe of the mariner's compaſs.

affirm,

affirm, that the word *verſorium* meant a particular rope. For my part, I am inclined to believe that it meant nothing more than the helm.

The firſt Authors on the verticity of the magnet.

4. Francis Cabeus, a Jeſuit of Ferrara, ſays, that the firſt thing he knows profeſſedly wrote on the direction, or verticity, of the magnet, was an epiſtle of *Petrus Peregrinus Gallus*, about the latter end of the 13th century, and that the peregrinations of this ſame Peter, in magnetical philoſophy, were not far from the truth. A few years after, this epiſtle was diſguiſed by one John Taſnier, who publiſhed it in his own name, under the title of *Opuſculum perpetuâ memoriâ dignißimum de naturâ et effectibus magnetis*. Some authors of note affirm, that this Petrus Peregrinus was no other than an aſſumed name of the Engliſh Friar Bacon, who flouriſhed in the 13th century. By the favour of Mr. Senebier, I received the following account of the above-mentioned letter:

"*Epiſtola Petri Peregrini de Marcourt, ad Sigerium*
"*de Foucancourt, Militem de Magnete.*

"The work contains a deſcription of that ſtone, the "means of finding the poles, its property of attracting "iron, and proves that the part of the magnet, which "is turned to the north, attracts that which is turned to

"the

" the ſouth. It then teaches the manner of employing " the magnet in aſtronomy, and of playing tricks, like " thoſe of Comus. It deſerves to be remarked, that the " author knew not that the magnet could be employed " in navigation; for, though he frequently ſpeaks *de* " *ſtella nautica*, he never ſpeaks of the uſe that might be " made of the magnetic needle in ſea voyages.

" *Vide Bibliotheca Bibliothecarum*, fol. II. p. 1400. " Catalogue of the Manuſcripts in the Library of Geneva, " by Senebier, p. 207."

Amongſt the manuſcripts of the univerſity of Leyden, there is a volume containing many ſcientific tracts, one of which is a letter of Peter Adſiger, which is dated in the year 1269, and contains an account of almoſt all the properties of the magnet that are known at this day. The attraction, repulſion, directive property of the magnet, the communication of thoſe properties to iron, the conſtruction of the azimuth compaſs, the uſe of the magnetic needle and the variation of it, are clearly mentioned in this curious letter, which, in fact, is a conciſe Eſſay on Magnetiſm *.

* Ample extracts of this letter, which is entitled *Epiſtola Petri Adſigerii, in Signationibus Naturæ Magnetis*, have been publiſhed by Mr. Cavallo, in the ſecond edition of his Treatiſe on Magnetiſm.

To

To give an account of all the numerous authors who have wrote on the properties of magnets, both natural and artificial, during the laſt and preſent centuries, would far exceed the brevity here intended; I ſhall, therefore, juſt add to thoſe already mentioned the names of Des Cartes, Dr. Gilbert, Wm. Barlow, Peter Van Muſchenbroeck, Savery, Dr. Knight, Mitchell, Canton, Paulus Friſius, Aepinus, and Cavallo. I have, indeed, heard of a laborious Italian Jeſuit, by name Scarella, who ſome years ago publiſhed two quarto volumes on Magnetiſm, but I could never procure the book. It ſeems, that Dr. Knight had once propoſed a work of the like extent on this ſubject; but he ſoon after laid aſide all thoughts of publiſhing it.

I ſhall now proceed to give ſome account of the principal properties of the magnet, reſerving the declination and variation of the needle for the latter part of this Eſſay.

AN

ESSAY ON MAGNETISM.

CHAPTER THE FIRST.

Of MAGNETISM *in General.*

Done at *New-York*, in the Year 1782, for a very ingenious young MIDSHIPMAN.

SECTION I.

A NATURAL magnet may not improperly be termed an iron ore; or rather a kind of native iron or virgin iron, as it is taken out of the earth. It reſembles very much caſt iron, and is endowed with the properties of attracting iron or other magnets (1). An artificial magnet is a piece of iron or ſteel, which has been endowed or impregnated with theſe ſame properties by art.

SECT. II. Every magnet, whether natural or artificial, has two principal points or poles, one whereof is called the North, and the other the South Pole. The ſimilar poles of all magnets repel, and the diſſimilar attract one another: that is, the north pole of one magnet repels the north pole of another, but it attracts the ſouth pole, and *vice verſa* (2).

SECT. III. If a ſlender bar of prepared iron or ſteel be properly placed between the poles of a good magnet, and kept there for ſome time, it will acquire a certain degree of magnetiſm, or, in other words, it will become an artificial magnet (3).

SECT. IV. If a good magnet, natural or artificial, be made of a ſpherical form, in which caſe it is called a *Terrella*, or little earth, and a ſmall piece of iron wire or needle is placed on its ſurface about midway between the two poles thereof, this needle will lie in the direction of a meridian, or rather parallel to the axis of the magnet; and, conſequently, will direct one of its ends to the north, and the other to the ſouth pole.

Further, if this little needle is moved along the ſurface of the magnet eaſtward or weſtward all round, it will keep the ſame ends directed to the poles reſpectively; but if the needle is moved toward either of the poles north or ſouth, it will, beſides keeping one of its ends directed towards that pole, begin to elevate itſelf on the end which is directed to the neareſt pole, the more and more as it advances; ſo that when it has arrived at this pole, it will ſtand perpendicular upon it.

If again, the little needle is moved toward the other pole of the magnet, the end which was elevated becomes lower and lower with a kind of tremulous motion, till the needle is nearly midway between the two poles, when

it

it falls flat, and becomes parallel to the axis of the magnet as before; and if it is carried on towards this other pole, it raiſeth itſelf gradually on the oppoſite end in the ſame manner, till it becomes alſo perpendicular upon that pole (4).

SECT. V. If a good magnet, natural or artificial, be made to float in quickſilver or on water, or be ſuſpended in ſuch a manner as to have little friction, one of its poles will direct itſelf towards the north, and the other towards the ſouth pole nearly; alſo if it is in the northern hemiſphere, (magnetically ſpeaking) the north pole of the magnet will deſcend below the horizontal line, while the ſouth pole is elevated above it; but if it is in the ſouthern magnetic hemiſphere, then the ſouth pole of the magnet will deſcend below, and the north pole will be elevated above the horizontal line. In either caſe, the meaſure of this inclination will be various, according to the ſituation of the place; but the whole exactly ſimilar to the experiments of the ſpherical magnet or terrella, and little needle, already mentioned (5).

SECT. VI. Upon any part of the ſurface of this globe, if a bar of prepared iron or ſteel be ſuſpended nearly in the ſame direction that the needle or magnet, having a free and unconfined motion, arranges itſelf in; and if this bar is kept in the ſame poſition for ſome time, it will become an artificial magnet (6).

SECT. VII. From what has been ſaid, we conclude, that the globe of this earth is ſtrongly impregnated with magnetiſm; for, like another magnet, it will communicate a conſiderable degree of magnetic power to any bar of prepared iron or ſteel, which may be upon its ſurface, if it is kept in a certain poſition for ſome time (ſee Sect. VI.). Alſo, that all ſuch maſſes of native or virgin iron, as are formed in the bowels of the earth, will be impregnated with this ſame general magnetic virtue, as well as the bar already mentioned.

Further, that any ſuch wires or ſlender bars of iron impregnated with magnetiſm, which have a free and unconfined motion, will be arranged nearly in a northerly and ſoutherly direction, as mentioned in Sect. V. by the magnetical power of the earth alone; and thence all the properties of the magnetic needle or mariners compaſs may be explained; the variation thereof only excepted.

SECT. VIII. I ſhall conclude this firſt chapter with obſerving, that as it is not intended for a ſyſtem of magnetiſm, I have only mentioned here ſuch leading principles as were neceſſary for explaining the declination and variation of the magnetic needle, which is to be the ſubject of the enſuing pages; yet I flatter myſelf, that whoever is thoroughly maſter of the principles here laid down, will very eaſily come to underſtand every other property of the magnet, though he has never before made that ſubject his peculiar ſtudy.

NOTES

NOTES AND ILLUSTRATIONS

ON

CHAPTER THE FIRST.

1. THERE are many rich iron ores which neither are, nor in that ſtate can they be impregnated with magnetiſm; the pure calces of iron cannot be rendered magnetical.

QUERE 1ſt.

Would it not therefore appear, that iron in its metallic form only is ſuſceptible of magnetiſm? As iron and ſteel are better purified than the natural magnet, and can more eaſily be made into a proper form, ſo the artificial are generally ſtronger than the natural magnets.

The longer a magnet is in proportion to its breadth, and the broader it is in proportion to its thickneſs, *cæteris paribus*, the ſtronger it generally is.

QUERE 2d.

Would it not therefore appear, that magnetiſm acts in proportion to the ſurface, and not as the quantity of matter like gravity? The magnetical machine of the late Doctor Gowen, Knight, is a further proof of this article. See Phil. Tranſ. Vol. LXVI. Part 2d. Anno 1776.

2. There are ſeveral ways of ſhewing this property of magnets; the moſt convenient I take to be by the common compaſs, the needle of which is an artificial magnet. Take therefore another magnet and point to it, and it will be found, that the north end of the magnet will repel the north, but it will attract the ſouth end of the needle.

Reverſe the magnet, and the ſouth end of the magnet will repel the ſouth end of the needle, but it will attract the north end: and as often as you reverſe the magnet, the needle will in like manner be reverſed. But to thoſe who are not much acquainted with this ſubject, the moſt convincing method of ſhewing the attraction as well as the repulſion of magnets, is by laying an artificial magnet in a little boat of light wood, or the like (ſee Plate II.); and ſetting it to float in a bowl of water, and pointing another magnet to it end to end.

3. I do not propoſe this as the beſt or only method of making artificial magnets; but I mentioned it here as a fact, for the ſole purpoſe of explaining ſome matters which I have further to offer in this Eſſay.

4. To ſhew this experiment to advantage, as it is a very material one; beſides the Terrella, it will be neceſſary to have a ſmall glaſs tube, with a round bulb, like thoſe which are uſed for thermometers; into which we drop

drop a bit of a fine ſewing needle, not above two-tenths of an inch long, which being applied to the Terrella, as in Plate III. may be eaſily guided round it, as is directed in Sect. IV.

5. But to exhibit theſe two properties at once, the beſt method is to have an inſtrument conſtructed in the manner of a dipping needle, ſuch as I contrived anno 1764. This machine, which I have called an Univerſal Magnetic Needle, or Obſervation Compaſs, is minutely deſcribed in the Philoſophical Tranſactions, vol. LXV. anno 1775; but a delineation of that inſtrument, which was omitted in the Phil. Tranſ., will be found in Plate I. of this Eſſay.

6. If this is a bar of hardened ſteel, it will take conſiderable time before it acquires any magnetical properties; but when it has once become magnetical, it will not loſe it eaſily; nor can the poles thereof be reverſed any other way, than by ſuch means as would have given it magnetiſm originally, if it had none.

This, therefore, we call fixed magnetiſm. But if the bar is of ſoft iron, it takes no length of time to become magnetical; for, in the northern hemiſphere, the moment you put ſuch a bar in the proper poſition, (ſee Sect. VI.) the lower end of it becomes a north pole, and the upper end a ſouth pole. (If it is in the ſouthern he-

miſphere the lower end is the ſouth, and the upper end the north pole.) Reverſe the ends of the bar, and the poles are accordingly reverſed, as often as you repeat the experiment.

The magnetiſm of this bar is therefore ſaid to be moveable, and almoſt every tongs or poker, with a common compaſs, is ſufficient to ſhew the experiment, (ſee Plate IV.) but by being often heated and cooled, and by generally ſtanding in a perpendicular poſition, if their magnetiſm ſhould appear to be fixed, let the lower end be ſtruck againſt the floor, or the ſtones of the chimney, and the poles will immediately be changed; a ſmart ſtroke of a hammer will have the ſame effect, and a ſhock of electricity will give magnetiſm even to ſteel. Several conjectures might be ſtarted from theſe experiments, which at preſent however we ſhall omit.

CHAPTER THE SECOND.

Of the Declination of the Magnetic Needle, commonly called the Variation of the Mariner's Compaſs.

SECTION I.

FROM attentively conſidering the principles laid down and explained in the foregoing part of this Eſſay, we conclude, that as the globe of this earth is a great magnet, ſo like every other magnet it muſt have two points or poles, which will act upon any magnetic or compaſs needle, in the ſame manner that another magnet or terrella would do; that is, it will cauſe one end of it to be directed to one of its magnetic poles, and the other end of it to the other. See Part I. Sect. 2, 4, 5, 6, and 7*.

It is likewiſe evident, that, according to the poſition of theſe magnetic poles, the compaſs needle will be differently affected, and from thence we may deduce the following caſes.

* But in this place it is proper to obſerve, that what we call the north magnetic pole of the earth, is in fact a ſouth pole; or, in other words, it is a magnetic pole, contrary to that pole of the needle which is attracted by, or directed towards, the north pole of the earth; becauſe the magnetic attraction takes place only between poles of different denominations: and for the ſame reaſon, what we call the ſouth magnetic pole of the earth, is in fact a north pole.

CASE I.

If the magnetic poles of this earth had coincided with the true poles thereof, there could have been no declination or variation of the mariner's compaſs in any part of the world, (i. e.) if the earth is uniformly magnetical; for in that caſe the needle, in pointing to the magnetic poles, muſt always have pointed to the true poles alſo. This needle would therefore be neceſſarily directed along the courſe of the meridian, or, in other words, it would have no declination either to the eaſt or weſt thereof.

CASE II. See PL. V.

If the magnetic poles were ſituated in the ſame meridian, and in oppoſite parallels upon that meridian which paſſes through the magnetic and true poles, from one of the magnetic poles to the other, and upon the oppoſite meridian all along, there could be no declination, for the reaſon mentioned in the former caſe: likewiſe, upon the equator there would be no declination; for though if one of the magnetic poles was only to act upon the needle, in paſſing along the equator to the diſtance of 90° in longitude eaſt or weſt, the declination would increaſe; ſo that at 90° diſtance from the line of no declination, it would be equal to the angle contained between the mag-

which are variouſly inclined to both, and they divide the ſurface of this globe into two parts; but theſe parts are not hemiſpheres, as in the laſt caſe; for they may be of very different extent.

If the magnetic poles are ſituated in meridians nearly oppoſite, the curvatures of thoſe lines are the leſs: that is, they become more like to Caſe 3d. But as the magnetic poles approach nearer to the ſame meridian, the curvature of the lines of no declination become greater till they almoſt touch one another, ſomething in form like the figure 8, and at laſt they complete the two great circles, as in Caſe 2d.

The lines of the ſecond order, which correſpond to the greateſt equatorial declination, if the magnetic poles are ſituated in meridians nearly oppoſite, have a declination nearly equal to the angle formed between the magnetic and true poles, as in Caſe 3d.

But as the magnetic poles approach toward the ſame meridian this declination decreaſes, till at laſt it entirely vaniſhes, together with the lines of the firſt order; and, as in Caſe 2d, leaving only the lines of the third order.

The other Halleyan lines in this caſe are ſo ſimilar to the former, that they require only to be referred to it.

I have therefore juſt to add, that whether the magnetic poles are ſituated in oppoſite parallels or not, makes as little difference in this caſe as in the former. (See the Plate.)

SECT.

SECT. II. Though I flatter myſelf, that the foregoing pages will be found to contain all the caſes that are neceſſary toward an explanation of the declination of the magnetic needle, at any one time; yet to thoſe who wiſh to be acquainted with this curious ſubject more fully, I would beg leave to recommend Mr. Euler's Reſearches, in the Berlin Memoirs for the Year 1757, a performance which will give ſome ſatisfaction even to thoſe who cannot enter into all his mathematical calculations; but for the convenience of ſuch gentlemen as may not ſoon have it in their power to conſult that volume, and as an example of the fourth Caſe, I ſhall tranſcribe from Mr. Euler's Map, annexed to the paper above-mentioned, the ſtate of Magnetiſm about the middle of this century. According to this ingenious author, the North Magnetic Pole ſeems then to have been ſituated near to the meridian, which paſſes by Cape St. Lucar, the South Point of Calefornia, and between the latitudes of 70° and 80° North.

(I do not think the obſervations are as yet ſufficient to authoriſe our being very particular *.)

The ſituation of the South Magnetic Pole, at that time, ſeems to have been above 60° more Weſtwardly, and near the latitude of 60° South †.

* Mr. Euler ſays 73° or 76°. † According to the ſame Author 55°.

SECT.

SECT. III. From this poſition of the magnetic poles then, the reſult is as follows. From the north magnetic pole a line of no declination commences, and by a route ſomewhat reſembling the letter S, it traverſes the continent of North America and the Atlantic Ocean, &c. to the ſouth pole of the earth, and then, by the arc of 180° to the ſouth magnetic pole.

From the ſouth magnetic pole this line of no declination proceeds, and in like manner traverſing the Pacific Ocean, paſſes by the iſlands of the Eaſt Indies, and through the continent of Aſia to the north pole of this earth, and ſo by the little arc of 180° to the north magnetic pole.

Theſe lines divide the ſurface of this globe into two parts; and in going eaſtward from the firſt to the ſecond line, over the eaſtern parts of North America, Europe, Africa, and a great part of Aſia, there is weſt declination; but from the ſecond to the firſt, over the eaſtern parts of Aſia, South America, the weſtern parts of North America, and the Pacific Ocean, there is eaſt declination. The declination of the lines of the ſecond order, correſponding to the greateſt equatorial declination, amounts in this caſe to 12°, and for the eaſt declination they croſs one another in north latitude 24°, and about 30° in longitude weſt of the meridian of California: for weſt declination the interſection is likewiſe in 24° north latitude, upon that part of the coaſt of the Red Sea, which is next to Arabia Felix.

If any perſon will take the pains to compare this with the charts of Meſſrs. Mountain and Dodſon for 1744 and 1756, he will find a ſurpriſing ſimilarity; and from what has been ſaid, with the help of theſe charts upon a common map of the globe, all the Halleyan lines may be drawn by hand. I have been the more particular on this part, as it is poſſible that each of theſe poſitions of the magnetic poles may have been, or hereafter may happen to be, their real ſituation; and as it is evident, that the fourth Caſe has been their poſition ever ſince any obſervations have been made on that ſubject, ſo it is probable that it will continue to be their ſituation for many ages to come. I ſhall therefore conclude this ſecond chapter, by obſerving, that if in ſome inſtances our beſt obſervations ſhould not perfectly agree with calculations, we are not therefore entirely to reject the theory; for, ſuppoſing the obſervations to be perfectly exact, which is not always the caſe, yet as this earth is undoubtedly a very heterogeneous body, it may not be uniformly magnetical, as ſhould be the caſe, if it was to agree entirely with the calculations, &c.

CHAPTER

CHAPTER THE THIRD.

FROM what has been ſaid in the two preceding chapters, we may conclude, 1ſt. That the earth is a great magnet, endowed with all the properties which have been obſerved in common magnets; 2dly, That the magnetic needle owes its directive property to the vicinity of this great magnet, in the ſame manner as we have ſhewn to happen with a ſmall needle, when placed upon a *terrella*, or globular magnet; and 3dly, That the direction of the needle muſt either coincide with, or deviate from, the meridian, according as the magnetic poles of the earth happen to be ſituated. After this, it will be neceſſary to examine the real ſtate of the matter; namely, to conſider, according to the beſt obſervations, the lines of declination throughout the world, a ſummary view of which will be contained in the preſent chapter.

SECTION I. That line, which I ſhall call the Atlantic line of no declination, ſeems to take its origin from the north magnetic pole, and croſſing the different meridians in a ſouth-eaſterly direction, reſembling in form the long letter S, it traverſes the continent of North America, enters the Atlantic Ocean to the northward of Charlestown, and ſo proceeds towards the ſouth pole. Upon

the weſt ſide of this line there is eaſt declination, and upon the eaſt ſide thereof, weſt declination; which laſt gradually increaſes as you go to the eaſtward, till you get beyond the Cape of Good Hope, or about midway between the Atlantic and the Eaſt India line of no declination, where it amounts to 31°, about the latitude of 48° ſouth, and then it regularly decreaſes to the Eaſt India line of no declination.

Again, as you go to the eaſtward of that line of no declination, the eaſt declination increaſes rapidly till you get to the eaſtward of New Zealand, where it is upwards of 13° even in that latitude; but from thence, as you proceed eaſtward, for about 40° in longitude, this declination appears to decreaſe; and again, it increaſes till you are to the eaſtward of Cape Horn, where, in the latitude of 51° ſouth, it amounts to 21° 28′, and then gradually decreaſes to the Atlantic line of no declination aforeſaid. Upon the whole it would appear, that theſe obſervations agree pretty nearly with the fourth general caſe deſcribed in the preceding chapter, except in that decreaſing eaſt declination to the eaſtward of New Zealand. But admitting that the vaſt body of water in the great Pacific Ocean, which cannot have any magnetic properties, ſhould have no effect in producing this irregularity, yet we are not to expect even that the ſolid parts of this globe can be ſo uniformly magnetical throughout, as to anſwer entirely with calculation in every part thereof.

SECT.

SECT. II. The magnetic needle not only declines, or varies from the true north, differently in different parts of the earth at any one time, but likewiſe in the ſame place this declination is different at different times; I would therefore call it, by way of diſtinction, the variation of the magnetic needle.

SECT. III. At London and Paris, where the moſt accurate obſervations have been made, towards the latter end of the ſixteenth century (and we cannot pretend to much earlier obſervations) there was between 11° and 12° of eaſt declination, which gradually decreaſed; ſo that in leſs than a hundred years afterwards, there was no declination at all in thoſe places. From 1657, at London, and 1666, at Paris, a weſt declination began, and has ever ſince increaſed gradually, though not uniformly, or in the direct proportion of the times; for ſuch is the nature of the magnetic declination, that, like the apparent motion of the planets, ſometimes it is faſter, ſometimes ſlower, at other times it is ſtationary; analogous alſo to the elongations of the inferior planets, at one time it is to the eaſt, and at another time to the weſt, alternately.

We may farther obſerve, that the declination lines of the ſame name have always reſpectively paſſed London ſome years before the ſame lines arrived at Paris; and the like obſervations have been made in other parts of the northern hemiſphere, that is, in this hemiſphere

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the Halleyan lines have regularly paſſed thoſe places firſt which lay moſt weſterly, and ſo in order, thoſe which lay more to the eaſtward. For in the latter end of the ſixteenth century, there was an eaſtern declination over moſt parts of Europe, while on the coaſt of North America a weſt declination prevailed; the line of no declination being then ſituated about the Azores. This line of no declination has ever ſince moved gradually eaſtward, the lines of eaſt declination receding before it, while the lines of the weſt declination have gradually followed it.

SECT. IV. In the ſouthern hemiſphere, however, it is quite otherwiſe; for about the latter end of the ſixteenth century, a line of no declination paſſed near to the Cape of Good Hope, upon the eaſt ſide of which there was weſt declination, and upon the weſt ſide thereof eaſt declination; each of which declinations, in going eaſtward or weſtward, gradually increaſed to a certain degree, and then in the ſame manner decreaſed to nothing, ſomewhere to the eaſtward of Java, one of the Eaſt India iſlands.

The declination in the Pacific Ocean has not as yet (1775) been ſo fully aſcertained, only in general we find, that the declination is eaſterly over moſt part of that extenſive ocean. The line of no declination, which was then ſituated a little to the eaſtward of the Cape of Good Hope, has ever ſince been moving to the weſtward, and

and the lines of eaſt declination have gradually receded before it, while thoſe of the weſt declination have followed it with a proportional pace; ſo that at the Cape of Good Hope there is now a conſiderable weſt declination (about 24°.*) and the line of no declination has moved many degrees to the weſtward thereof.

SECT. V. From the preceding obſervations then it plainly appears, that the Halleyan lines in the ſouthern hemiſphere do gradually move from eaſt to weſt, while the motion of thoſe lines in the northern hemiſphere is from weſt to eaſt; and here we ſhall reſt the matter for the preſent.

I ſhall juſt beg leave to obſerve, that in treating of this ſubject, I have all along only endeavoured to explain the manner in which magnetiſm acts upon this globe; yet if the preceding concluſion be admitted, viz. that the progreſſive motion of the lines of declination in the northern hemiſphere is conſtantly from weſt to eaſt, and in the ſouthern hemiſphere from eaſt to weſt, this diſcovery will be of as great uſe to us in framing, regulating, or judging of our future charts or tables of the declination or variation of the mariner's compaſs, and will anſwer the purpoſes of navigation as well, as if we were thoroughly acquainted with the primary cauſes of all the phenomena of magnetiſm.

* The author received this and other informations from Colonel Gordon, commander of the Dutch forces at the Cape.

CHAPTER THE FOURTH.

An Attempt to explain the Cauſe of the Variation of the Magnetic Needle.

WROTE IN THE YEAR 1793.

——— Si quid noviſti rectius iſtis,
Candidus imperti: ſi non, his utere mecum.
Horat. Epiſt. VI. lib. 1.

SECTION I.

IF we were to enter into the hiſtory of magnetiſm, the diſcovery of the mariner's compaſs, or even that curious ſubject the declination or variation of the magnetic needle, we ſhould find that the compaſs was known probably before the year 1181, and the variation at leaſt as early as the month of Auguſt, 1269*, though that ſubject was not brought to any kind of regularity till the time of Dr. Halley. The reſearches and obſervations of that ingenious gentleman have been of the utmoſt ſervice in navigation, however whimſical his theory may have appeared to ſome people.—But this for the preſent we paſs over.

* See the Edinburgh periodical publication, entitled, The Bee, vol. xiii. N° 3. Columbus obſerved the variation of the compaſs in his firſt voyage, anno 1492.—Muſſchenbrek de Magnete, Exp. 97.

SECT. II. On the principles of the ingenious Mr. Euler (ſee the Berlin Acts, volume for the year 1757) the declination of the magnetic needle may in great meaſure be accounted for. That is, ſuppoſing the magnetic poles of this earth to be, at any one time ſince actual obſervations have been made on that ſubject, only two, but not ſituated diametrically oppoſite to each other. (See Cavallo's Treatiſe on Magnetiſm, p. 117.) It is alſo well known that the magnetic declination is not only different in different parts of the earth at the ſame time, but that in a courſe of years it alſo becomes different in the ſame place. Farther, that this declination in the ſame place is not only different in different years, but even the afternoon declination is generally different from the forenoon declination of the ſame day.

SECT. III. This ſubject appeared very unaccountable till the year 1759, when the late Mr. John Canton explained it in a very ingenious manner; for having found by experiment, that by heating a magnet it loſt part of its attractive power, and by letting it cool, it recovered that power again; he likewiſe diſcovered by repeated obſervations, that while the eaſtern parts of the earth were heated by the ſun in the forenoon, and conſequently had their magnetic powers diminiſhed, the needle generally inclined more to the weſtward, and that after the ſun had paſſed our meridian, and the weſtern parts

of the earth began to be heated, while thoſe on the eaſt of the meridian were cooled, the declination of the needle was leſs weſterly by ſeveral minutes, and that by next morning it had returned to its former poſition nearly.—We ſay nearly, for after a courſe of more than twelve months attentive obſervation he found, that the declination was upon the whole increaſed of about ten or twelve minutes of a degree. That this increaſe was occaſioned by the ſun's heat, appeared the more probable, as it took place moſtly in the ſummer months; and during the winter months there was but little alteration, as appears from the following table *:

The mean difference of diurnal variation for each month in the year 1759.

January	7′ 8″	July	13′ 14″
February	8. 58.	Auguſt	12. 19.
March	11. 17.	September	11. 43.
April	12. 26.	October	10. 36.
May	13. 0.	November	8. 9.
June	13. 21.	December	6. 58.

SECT.

* Mr. Canton, it ſeems, made in 603 days about 4000 obſervations on the ſubject, with an excellent variation compaſs about nine inches in diameter. In 574 of thoſe days the variation was regular, and conſequently only 29 irregular, according to his ſyſtem. Mr. Canton's opinion was, that when the variation increaſes from about eight or nine o'clock in the morning till one or two in the afternoon, then becoming ſtationary

SECT. IV. It muſt be allowed, according to the obſervations of ſeveral ingenious gentlemen, that the collective magnetiſm of this earth ariſes from the magnetiſm of all the ferruginous bodies therein contained, and that the magnetic poles ſhould therefore be conſidered as the centres of the powers of thoſe magnetic ſubſtances. Theſe poles muſt therefore change their places according as the magnetiſm of ſuch ſubſtances is affected; nd if with Mr. Canton we allow that the general cauſe of the diurnal variation ariſes from the ſun's heat in the forenoon and afternoon of the ſame day, it will naturally occur, that the ſame cauſe, being continued, may be ſufficient to produce the general variation of the magnetic needle for any number of years. For we muſt conſider that ever ſince any attentive obſervations have been made on this ſubject, the natural direction of the magnetic needle in Europe has been conſtantly moving, from weſt to eaſt, and that in other parts of the world it has continued its motion with equal conſtancy.

for ſome time, after that returning back again to its former ſtation in the night, or by next morning, it is regular. But he calls it irregular when the needle moves eaſtward in the hotter part of the morning, or weſtward in the latter part of the afternoon; alſo when it moves either way in the night, or ſuddenly, viz. when it moves both ways in a ſhort ſpace of time. The cauſes of thoſe irregularities he attributes to ſubterraneous heat, to the Aurora Borealis, &c.

SECT. V. As we muſt therefore admit that the heat in the different ſeaſons depends chiefly on the ſun, and upon the whole that the months of July and Auguſt will probably be found the hotteſt, while January and February are the coldeſt months of the year; and that the temperature of the other months falls into the reſpective intermediate degrees; though from calculation we can ſcarce pretend to aſcertain the abſolute heat of any particular month or day; ſo we muſt conſider the influence of heat upon magnetiſm to operate in the like manner, viz. that for a ſhort time it ſcarcely manifeſts itſelf; yet in the courſe of a century, the conſtancy and regularity thereof becomes ſufficiently apparent. It would therefore be idle to ſuppoſe, that ſuch an influence could be derived from an uncertain or fortuitous cauſe. But if it be allowed to depend upon the conſtancy of the ſun's motion *, and this appears to be a cauſe ſufficient to explain the phænomena, we ſhould (agreeably to Newton's firſt law of philoſophizing) look no farther.

SECT. VI. As we therefore conſider the magnetic powers of the earth to be concentrated in the magnetic poles, and that there is a diurnal variation of the magnetic needle, theſe poles muſt perform a ſmall diurnal revolution proportional to ſuch variation, and return again to

* See Dr. John Hunter on Heat, Phil. Tranſ. for 1788.

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the ſame point nearly.—Suppoſe then that the ſun in his diurnal revolution paſſes along the northern tropic, or along any parallel of latitude between it and the æquator, when he comes to that meridian in which the magnetic pole is ſituated, he will be much nearer to it, than in any other; and in the oppoſite meridian he will of courſe be the fartheſt from it. As the influence of the ſun's heat will therefore act moſt powerfully at the leaſt, and leſs forcibly at the greateſt diſtance, the magnetic pole will conſequently deſcribe a figure ſomething of the elliptical kind; and as it is well known that the greateſt heat of the day is ſome time after the ſun has paſſed the meridian, the longeſt axis of this elliptical figure will lie north-eaſterly in the northern, and ſouth-eaſterly in the ſouthern hemiſphere. Again, as the influence of the ſun's heat will not from thoſe quarters have ſo much power, the magnetic poles cannot be moved back to the very ſame point, from which they ſat out; but to one which will be a little more northerly and eaſterly, or more ſoutherly and eaſterly, according to the hemiſpheres in which they are ſituated. The figures therefore which they deſcribe, may more properly be termed elliptoidal ſpirals *.

* The north magnetic pole may by this means be carried, with a ſlow but conſtant motion, more and more to the north-eaſtward, till it arrives at the region of the greateſt cold, which, by the bye, is ſuppoſed to be at ſome degrees diſtance from the natural pole of the earth. And likewiſe the other magnetic pole will be carried, &c.

SECT. VII. In this manner the variation of the magnetic needle in the northern hemiſphere may be accounted for. But with reſpect to the ſouthern hemiſphere we muſt recollect, that though the lines of declination in the northern hemiſphere have conſtantly moved from weſt to eaſt, yet in the ſouthern hemiſphere, it is equally certain that they have moved from eaſt to weſt, ever ſince any obſervations have been made on the ſubject*. Is it poſſible then that the magnetic pole in the ſouthern hemiſphere can move from eaſt to weſt, whilſt that in the northern hemiſphere moves from weſt to eaſt?—I think not. But we muſt conſider this matter a little more attentively. In the firſt place it muſt be obſerved, that in ſpeaking of the declination or variation of the magnetic needle, we always refer to the north end of the needle only. Thus, when the north end of the needle points to the weſt of the meridian, we ſay it has ſo many degrees weſt variation, though the ſouth end thereof points as many degrees to the eaſtward. Again, when the north end of the needle points to the eaſtward of the meridian, we ſay it has eaſt variation, though the ſouth end points to the weſtward thereof. And the ſame language is uſed in the ſouthern as in the northern hemiſphere; ſo that if the ſouth magnetic pole, which governs the needle in that hemiſphere, move to the eaſtward, oc-

* See Cavallo's Treatiſe on Magnetiſm.

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caſions, as we ſay, the needle to have weſt variation; and, on the contrary, if it move to the weſtward, it makes what we term eaſt variation. This therefore is the cauſe, on account of which the lines of magnetic declination, or Halleyan curves, as they are now commonly called, appear to have a contrary motion in the ſouthern hemiſphere, to what they have in the northern; though both the magnetic poles of the earth move in the ſame direction, that is from weſt to eaſt*.

SECT. VIII. This might be made ſtill more evident by a diagram, or by means of the mariner's compaſs and a common magnet: and here we might reſt the matter for the preſent, but I cannot help mentioning the idea of Dr. Gowen Knight, a gentleman undoubtedly known to have

* In the northern hemiſphere there was a line of no variation, which had eaſt variation on its eaſtern ſide, and weſt variation on its weſtern ſide. This line evidently moved from weſt to eaſt, during the two laſt centuries; the lines of eaſt variation moving before it, while the lines of weſt variation followed it with a proportional pace. Theſe lines firſt paſſed the Azores or Weſtern Iſlands, then the meridian of London, and after a certain number of years ſtill later, they paſſed the meridian of Paris. But in the ſouthern hemiſphere there was another line of no variation, which had eaſt variation on its weſtern, and weſt variation on its eaſtern ſide; the lines of eaſt variation moving before it, while thoſe of the weſt variation followed it. This line of no variation firſt paſſed the Cape des Aiguilles, and then the Cape of Good Hope; the lines of 5°, 10°, 15°, and 20°, weſt variation following it, the ſame as was the caſe in the northern hemiſphere, but in contrary direction.

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been well acquainted with practical as well as theoretical magnetiſm. His opinion was, that this earth had originally received its magnetiſm, or rather that its magnetical powers had been brought into action, by a ſhock, which entered at about the ſouthern, and paſſed out at the northern tropic. His meaning appears to have been, that this was the courſe of the magnetic fluid, and that the magnetic poles were at firſt diametrically oppoſite to each other.

SECT. IX. In this Eſſay our intention has all along been to avoid ſuppoſitions merely theoretical; for we do not pretend to explain the cauſes of magnetiſm on any theory however plauſible. Yet we have no objection to Dr. Knight's ſuppoſition, that the magnetic poles might at firſt have been oppoſite to each other; though, according to Mr. Canton's doctrine, they would not have long continued ſo; for from the intenſe heat of the ſun in the torrid zone, according to the principles already explained, the north pole muſt have ſoon retired to the north-eaſtward, and the ſouth pole to the ſouth-eaſtward. It is alſo curious to obſerve, that on account of the ſouthern hemiſphere being colder upon the whole than the northern hemiſphere*, the magnetic poles would have moved with

* It is well known that in the courſe of the year the ſun is for about eight days longer in the northern than in the ſouthern hemiſphere; but without entering into all the cauſes of this effect, it is here ſufficient to obſerve that this fact has been indiſputably proved.

unequal

unequal pace; that is, the north magnetic pole would have moved farther in any given time to the north-eaſt, than the ſouth magnetic pole could have moved to the ſouth-eaſt. And, according to the opinions of the moſt ingenious authors on this ſubject, it is generally allowed, that at this time the north magnetic pole is conſiderably nearer to the north pole of the earth, than the ſouth magnetic pole is to the ſouth pole of the earth.

Charlotte Street, Sept. 30, 1794.

P. S. Several ingenious ſea officers are of opinion, that in the weſtern parts of the Engliſh Channel the variation of the magnetic needle has already begun to decreaſe; having in no part of it ever amounted to 25°. There are, however, other perſons who aſſert, that the variation is ſtill increaſing in the Channel, and as far weſtward as the 15th degree of longitude and 51° of latitude, at which place they ſay that it amounts to about 30°.

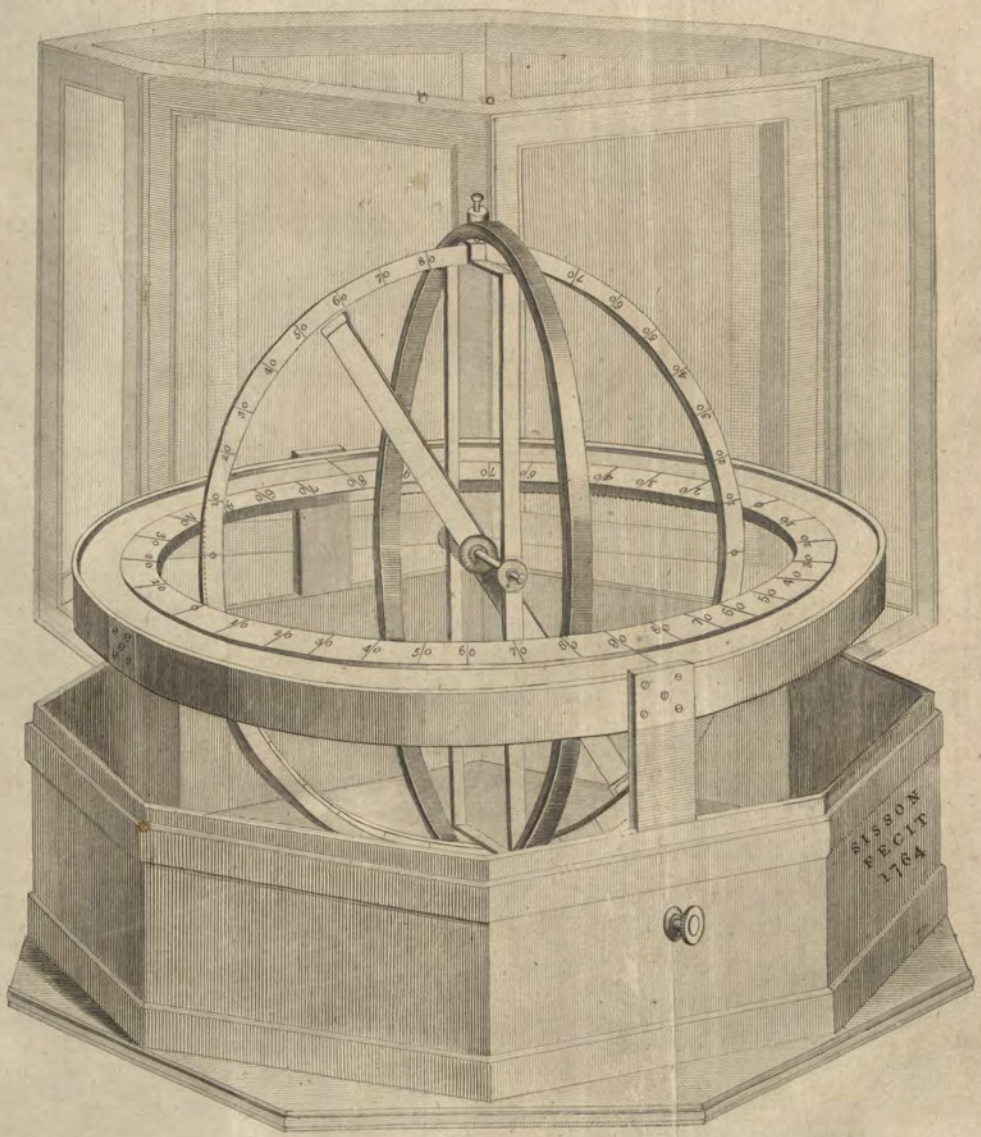
AN EXTRACT OF A LETTER

From the ingenious Dr. NOOTH, to the AUTHOR.

Dated Quebec, Nov. 1ſt, 1793.

AS I am well convinced, that you will with pleaſure receive any communication reſpecting the magnetic influence, I ſhall juſt tell you, that lately I accidentally found that there was a diminution in the variation of this place ſince the year 1785. In that year Major Williams and Major Holland, ran a meridian on the plains of Abraham; and on the ſeveral ſtones that were placed in the line of the meridian they marked the longitude, latitude, and variation. At that time the variation, by the mean of many compaſſes, was 12° 35′; at preſent I find it only 12° 5′; and this has been aſcertained by at leaſt thirty needles, ſo that there can be no doubt of the fact.

THE END.



Dipping Needle by John Lorimer M.D. *See the Philos. Trans. Vol.* LXV.

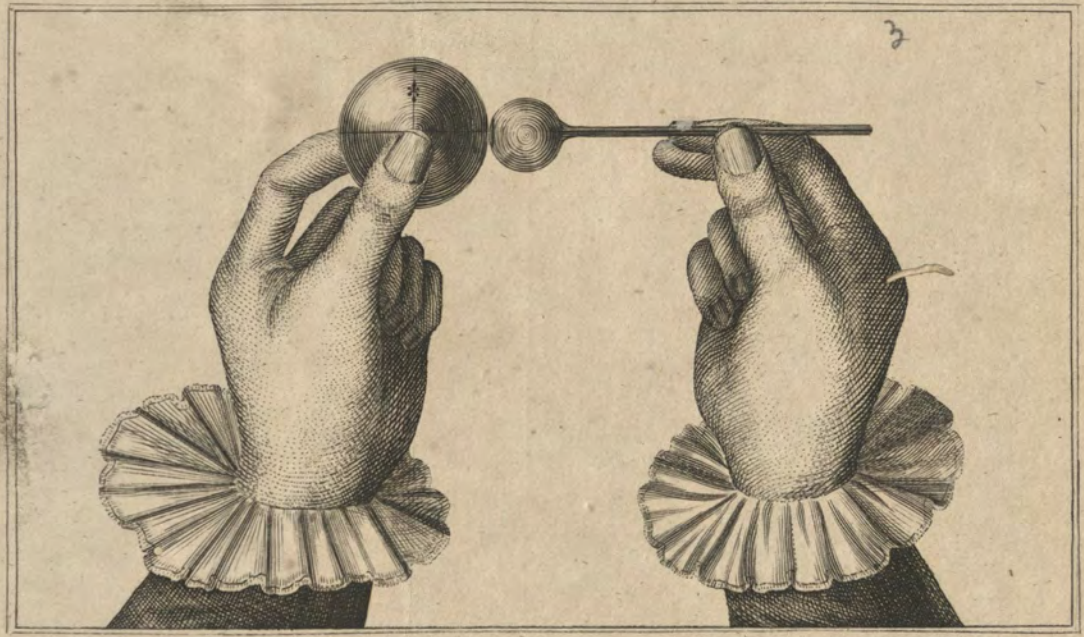
Basire Sc.

PRINCIPAL PROPERTIES of the MAGNET proved by EXPERIMENT.

Pl. II.

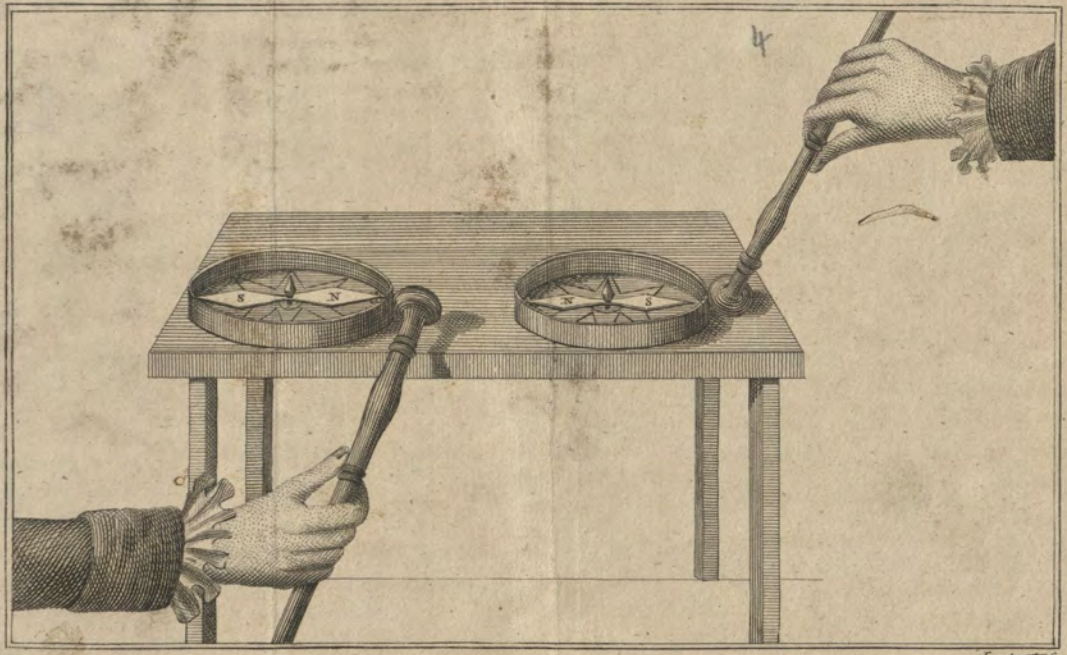
Longmate sc.

The PROPERTIES of the TERRELLA. *Pl. III.*



Longmate fc.

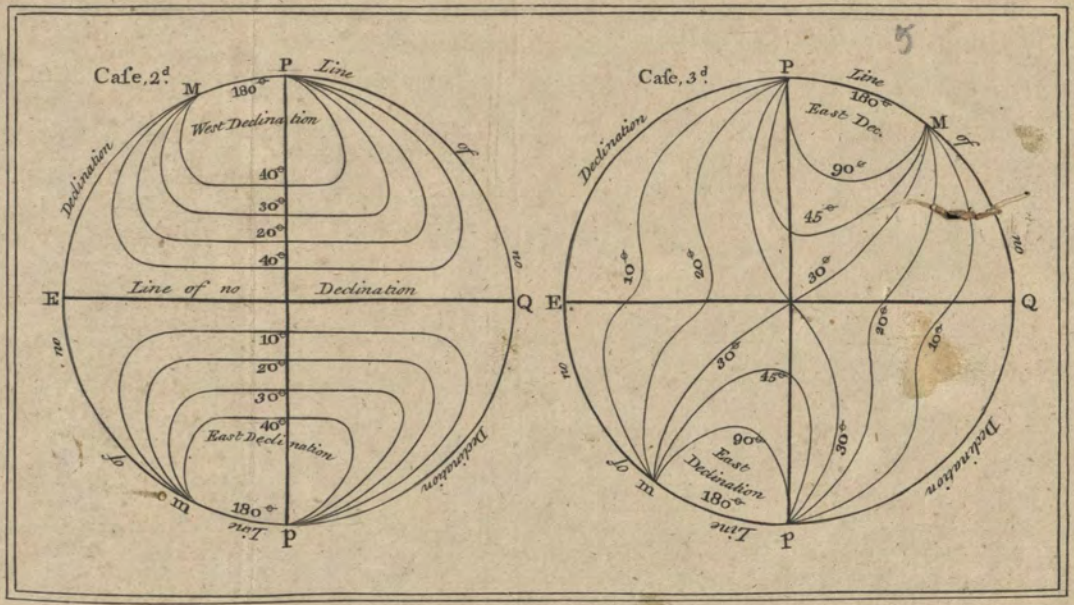
MAGNETISM of the EARTH proved by SOFT IRON. *Pl. IV.*



Longmate sc.

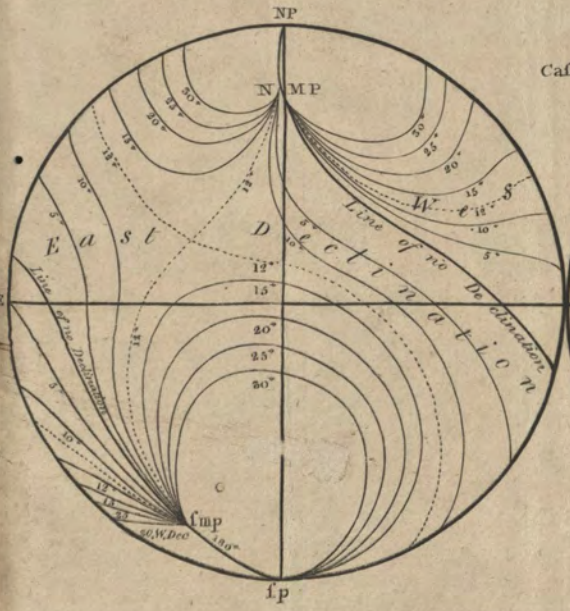
LINES OF MAGNECTIC DECLINATION.

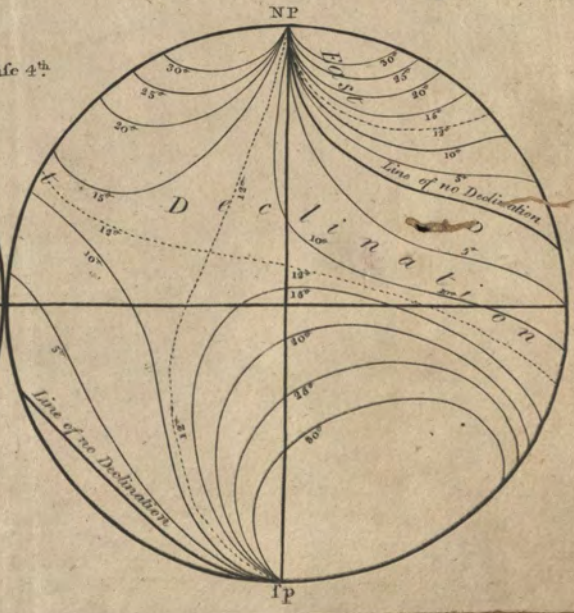
Pl. V.



GENERAL LINES of the MAGNETIC DECLINATION or VARIATION. Pl. VI.

Case 4th.





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